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(54) [Title of the Invention] Electron Emission Device, Method of Manufacturing the Same, and Electron Source and Image Forming Apparatus using Electron Emission Device

(57) [Abstract]

[Object] To provide an electron emission device having a uniform electron emission characteristic, which is manufactured by simple manufacturing processes.

[Constitution] An electron emission device formed in such a manner that device electrodes 2 and 2' are formed on an insulating substrate 1 to a shape in which the electrodes 2 and 2' are connected to each other, minute intervals L of 500 nm or less are formed by focused ion beam, and a deposit 3 essentially containing carbon is formed in the minute interval by thermal treatment at atmosphere containing hydrocarbon gas.

[What is claimed is]

[Claim 1] An electron emission device characterized by at least comprising an insulating substrate; a pair of electrodes formed on the insulating substrate, the pair of electrodes facing to each other so as to interpose a minute gap therebetween; and a deposit deposited in the minute gap, the deposit essentially containing carbon.

[Claim 2] The electron emission device according to claim 1, wherein the minute gap is 500 nm or less.

[Claim 3] The electron emission device according to claim 1 or 2, wherein the deposit essentially containing carbon is an aggregate formed of a fibrous material.

[Claim 4] The electron emission device according to claim 3, wherein the fibrous carbon is formed of graphite, amorphous carbon or mixture of graphite and amorphous carbon.

[Claim 5] A method of manufacturing an electron emission device is characterized by comprising a step of forming a pair of electrodes on an insulating substrate, the pair of electrodes facing to each other so as to interpose a minute gap therebetween; and a step of depositing a deposit in the minute gap, the deposit essentially containing carbon.

[Claim 6] The method of manufacturing an electron emission device according to claim 5, the depositing step of the deposit essentially containing carbon is a thermal decomposition step of carbon compound.

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[Claim 7] The method of manufacturing an electron emission device according to claim 6, wherein the carbon compound is hydro carbon.

[Claim 8] The method of manufacturing an element emission device according to claim 7, wherein the hydrocarbon is ethylene.

[Claim 9] The method of manufacturing an element emission device according to any one of claims 6 to 8, wherein the decomposition step of the carbon compound is a heating step at atmosphere containing the carbon compound.

[Claim 10] The method of manufacturing an electron emission device according to any one of claims 5 to 9, the deposition step of the deposit essentially containing the carbon comprises a step of forming metal fine particles in the inter-electrode minute gap; and a step of depositing fibrous carbon by use of the metal fine particles as a nucleus by thermally decomposing the carbon compound.

[Claim 11] The method of manufacturing an electron emission device according to claim 10, wherein the step of forming the metal fine particles comprises a step of coating organic complex solution of the metal onto the inter-electrode gap; a step of baking the organic metal complex to convert the organic metal complex to metal oxide; and a step of reducing the metal oxide and aggregating the metal oxide.

[Claim 12] The method of manufacturing an electron emission device according to claim 11, wherein the step of reducing and aggregating the metal oxide is a step of exposing the metal oxide at atmosphere containing hydrogen gas or a step of thermally heating the metal oxide at this atmosphere.

[Claim 13] The method of manufacturing an electron emission device according to any one of claims 10 to 12, wherein the deposition step of the fibrous carbon is a step of performing a thermal treatment at a thermal decomposition temperature or more of ethylene at atmosphere containing the ethylene.

[Claim 14] The method of manufacturing an electron emission device according to any one of claims 10 to 12, wherein the step of reducing and aggregating the metal oxide is performed by thermally treatment for the metal oxide at a thermal decomposition temperature or less of ethylene at atmosphere containing ethylene gas, and subsequently heating the metal oxide to the thermal decomposition temperature or more of ethylene at the same atmosphere, thus performing the deposition step of the fibrous carbon.

[Claim 15] An electron source is characterized by comprising at least one device

array which is constituted by arranging the plurality of electron emission devices claimed in any one of claims 1 to 4 in parallel and coupling the plurality of electron emission devices to each other.

[Claim 16] An electron source is characterized by comprising at least one device array which is constituted by arranging the plurality of electron emission devices claimed in any one of claims 1 to 4, wherein wirings for driving the devices are matrix-arrayed.

[Claim 17] An image formation apparatus is characterized by comprising the electron source claimed in claim 15, an image formation member, and a control electrode for controlling an electron beam emitted from each electron emission device by an information signal.

[Claim 18] An image formation apparatus is characterized by comprising the electron source claimed in claim 16 and an image formation member.

[Detailed Description of the Invention]

[0001]

[Field of Industrial Application] The present invention relates to an electron emission device, an electron source constituted by arranging the plurality of electron emission devices, and an image formation apparatus such as a display device and an exposure apparatus, which are constituted by use of the electron source, and furthermore, to a method of manufacturing the foregoing electron emission device.

[0002]

[Prior Art] Two kinds of thermoelectron source and cold cathode electron source have been heretofore known as an electron emission device, and there have been a field emission type (hereinafter referred to as a FE type) cold cathode electron source, a metal/insulating layer/metal type (hereinafter referred to as a MIM type) cold cathode electron source and a surface conduction type cold cathode electron source.

[0003] As an example of the FE type, "Field emission", Advance in electron Physics, 8, 89 (1956) by W. P. Dyke & W. W. Dolan, and "PHYSICAL Properties of thin-film field emission cathodes with molybdenum cones" J. Appl. Phys. 47, 5248 (1976) by C. A. Spindt and the like have been known.

[0004] Furthermore, as an example of MIM type, "The tunnel-emission amplifier", J. Appl. Phys., 32, 646(1961) by C. A. Mead and the like has been known.

[0005] Furthermore, as an example of the surface conduction type electron mission device, the one has been described in Radio Eng. 10 (1965) Electron Phys. by M. I. Elinson.

[0006]

[Subjects to be Solved by the Invention] When the display device and the like are constructed by use of the plurality of electron emission devices as described above, uniformity of electron emission characteristics of the devices is required, and uncomplicated processes for the fabrication of the devices showing the uniform electron emission property is required. Accordingly, as to the electron emission device, eager examinations have been conducted to meet such a demand, and to achieve further simplification of the manufacturing steps and more excellent device.

[0007] An object of the present invention is to provide an electron emission device with high reliability, which shows a uniform electron emission property without accompanying complicated processes, and further another object of the present invention is to constitute an electron source by use of the electron emission device, and an image formation apparatus.

[0008]

[Means for Solving the Subjects and Operation] The invention defined in claims 1 to 4 is an electron emission device which achieves the above described object, and characterized in that a pair of electrodes are provided on an insulating substrate so as to interpose a minute gap therebetween; and a deposit is provided in the minute gap, the deposit essentially containing carbon.

[0009] The invention defined in claims 5 to 14 is a manufacturing method of the foregoing electron emission device, and is characterized in that a pair of electrodes is provided on an insulating substrate so as to interpose a minute gap therebetween; and a deposit is provided in the minute gap, the deposit essentially containing carbon.

[0010] The invention defined in claims 15 and 16 is an electron source characterized in that the plurality of electron emission devices are arranged, and the invention defined in claim 17 and 18 is an image formation apparatus characterized by using the respective electron sources.

[0011] The present invention will be described in detail below.

[0012] Fig. 1 is a drawing showing a basic constitution of an electron emission device of the present invention. In the drawing, reference numeral 1 denotes

an insulating substrate; 2 and 2', a device electrode; and 3, a deposit essentially containing carbon.

[0013] As the substrate 1, enumerated are, for example, quartz glass, glass in which the content of impurities such as Na is reduced, soda lime glass, a stacked body in which  $\text{SiO}_2$  is stacked on the soda lime glass by a sputtering method or like, ceramics such as alumina and the like.

[0014] As a material of the device electrodes 2 and 2' facing to each other, a general conductive material is used. A printing conductor composed of a metal including, for example, Ni, Cr, Au, Mo, W, Pt, Ti, Al, Cu, Pd and the like or alloy of these metals, a metal including Pd, Ag, Au,  $\text{RuO}_2$ , Pd-Ag and the like or metal oxide of these metals, glass and the like, a transparent conductor such as  $\text{In}_2\text{O}_3\text{-SnO}_2$  and a semiconductor material such as polysilicon are properly selected.

[0015] The device electrode gap L and the device electrode length W are designed according to a type applied and the like.

[0016] The device electrode length W should preferably be several  $\mu\text{m}$  to several hundred  $\mu\text{m}$  in consideration of the resistivity of the electrode and the electron emission characteristic. The thickness d of the device electrode should preferably be several hundred  $\text{\AA}$  to several  $\mu\text{m}$ .

[0017] The gap L between the device electrodes should be minute, and should preferably be equal to 500 nm or less.

[0018] Descriptions for a method of manufacturing an electron emission device of the present invention will be made based on Fig. 2. Note that in Fig. 2, the same reference numerals as those in Fig. 1 shows the same member.

[0019] (A) After the substrate 1 is fully washed out by a cleaning material, pure water and organic solvent, a device electrode material is deposited thereon by a vacuum deposition method, a sputtering method or the like. Afterward, a state where the device electrodes 2 and 2' are communicated with each other is formed on the plane of the substrate 1 by use of a photolithography technique (Fig. 2(a)).

[0020] (B) Next, a predetermined gap L is formed between the device electrodes 2 and 2' by use of a focused ion beam (FIB) (Fig. 2(b)). The gap L can be formed by a method by use of processes of photolithography or by a method in which a step difference is previously provided in the substrate 1, in addition to the foregoing FIB.

[0021] (C) A deposit essentially containing carbon is deposited in the gap L. In the present invention, the deposit should preferably be fibrous carbon, which is formed of graphite or amorphous carbon.

[0022] The fibrous carbon is generated when hydrocarbon such as benzene and CO are thermally decomposed at a vapor phase by use of fine particles as catalyst, and the fibrous carbon shows irregular bending, and may accompany constrictions (for example, R. T. K. Baker and P. S. Harris: Chemistry and Physics of Carbon, Vol. 14 p84 to 165 by Philip L. Walker Jr. and Petere A. Thrower, MARCEL DEEKER, inc.).

[0023] Catalyst activity in the decomposition reaction of hydrocarbon gas on the surface of a metal such as Fe has been investigated from a long time ago, and there have been many reports as to the decomposition of ethylene (for example, "Chemistry of ethylene on surface of transition metal" by Eriko Yagazaki & Yasuhiro Iwasaki, Surface, Vol. 29, pp 879 to 891, 1991).

[0024] In the case where fine particles of Fe exist, the fact that the fibrous carbon is formed around the nucleus of the fine particles by performing the thermal treatment at the atmosphere in which the hydrocarbon exist has been well known as described above. The Fe fine particles are formed by reducing a Fe compound forming a part of a ferrite substrate. The inventors of the present invention found that fine particles formed of Pd widely used in a field of the electron emission device serve also as the nucleus in forming the fibrous carbon similarly to Fe. Accordingly, in the present invention, when Pd is used as the nucleus for forming the fibrous carbon, it is possible to control the process maximum temperature to 450 °C or less (when Fe is used, the process maximum temperature ranges from 950 to 1000 °C). Therefore, Pd is preferable in terms of influences on other members and manufacturing cost.

[0025] To be concrete, after organic metal complex solution using Pd and the like is coated and thermally baked, thus converting the solution to a metal oxide, the metal oxide is exposed to atmosphere containing hydrogen gas or subjected to a thermal treatment at this atmosphere, and hence the metal oxide is reduced and aggregated. Thus, metal fine particles 21 are produced (Fig. 2(c)).

[0026] In the present invention, as the nucleus for forming the fibrous carbon, Ni is preferably used in addition to the foregoing Fe and Pd, The nucleus needs not to assume a shape of fine particles. The same effects can be obtained if it is forms, such as a projection shape, which is a singular point of a growth of

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the fibrous carbon.

[0027] The fibrous carbon is deposited by using the foregoing metal fine particles as the nucleus (Fig. 2(d)). The deposition method in which carbon compound such as hydrocarbon is thermally decomposed as described above at atmosphere containing ethylene gas may be employed. For example, the carbon compound may be subjected to the thermal treatment at atmosphere containing ethylene gas at a temperature higher than the thermal decomposition of ethylene. In addition to ethylene, hydrocarbon gas such as methane, propane and propylene and vapor of organic solvent such as methanol and acetone can be used.

[0028] The inventors of the present invention confirmed that the fibrous carbon is not formed at a temperature of 400 °C or less. On the other hand, at a temperature higher than 400 °C, it is possible to form the fibrous carbon over a fully wide range. The fibrous carbon similar to that of an embodiment to be described later is formed by a thermal treatment at 900 °C. However, as described above, since other members of the device are affected by the thermal treatment at the high temperature, a thermal treatment carried out at a temperature lower than 900 °C or less is preferable. Actually, the temperature of the thermal treatment should be set based on a heat-resistant temperature of the electrode and the substrate.

[0029] Moreover, the reduction step of the foregoing metal fine particles is, for example, performed at a temperature lower than the thermal decomposition temperature of ethylene at atmosphere containing ethylene gas, and subsequently a thermal treatment at the thermal decomposition temperature or more of ethylene is performed, whereby the reduction step of the metal fine particles and the deposition step of the fibrous carbon can be conducted continuously, and this is preferable in terms of simplification of the manufacturing steps.

[0030] When a sample was observed by a scanning electron microscope, which was obtained by thermally treating a Pd particle-dispersed film at ethylene atmosphere, in which Pd fine particles were formed, by the similar step as that of an embodiment to be described later, on a silicon substrate having a surface on which a thermal oxide film was formed, the fibrous carbon was observed. It was confirmed by an X-ray photoelectron spectrometry (XPS) and a RAMAN spectrometry that this was carbon. Moreover, when the fibrous carbon was



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observed by a transmission electron microscope, a lattice image was observed, and the fibrous carbon possesses crystallinity. Note that the lattice image is very distorted, and the crystallinity is poor.

[0031] Fig. 3 is a schematic constitution view showing an example of a measurement evaluation system for measuring an electron emission characteristic of the electron emission device, and descriptions of the measurement evaluation system will be made.

[0032] In Fig. 3, the same reference numerals as those of Fig. 1 denote the same members. Reference numeral 31 denotes a power source for applying a device voltage  $V_f$  to the device; 30, a current meter for measuring a device current  $I_f$  flowing between the device electrodes 2 and 2'; 34, an anode electrode for capturing an emission current  $I_e$ ; 33, a high voltage power source for applying a voltage to the anode electrode 34; 32, a current meter for measuring the emission current  $I_e$ ; 35, a vacuum apparatus; and 36, an air exhaustion pump.

[0033] The electron emission device, the anode electrode 34 and the like are installed in the vacuum apparatus 35. In this vacuum apparatus 35, necessary instruments such as a vacuum meter (not shown) are provided, so that measurement evaluations of the electron emission device can be performed under a desired vacuum.

[0034] The air exhaustion pump 36 is constituted by an ordinary high vacuum apparatus system composed of a turbo pump, a rotary pump and the like, and a ultra high vacuum apparatus system composed of an ion pump and the like. Moreover, the measurement evaluation system is designed so that the whole of the vacuum apparatus 35 and the substrate 1 of the electron emission device can be heated to about 200 °C by a heater.

[0035] The basic characteristic of the electron emission device, which is to be described below, is based on measurement conducted in such a manner that a voltage of the anode electrode 34 of the foregoing measurement evaluation system is set to 1 kV to 10 kV, and the distance  $H$  between the anode electrode 34 and the electron emission device is set to 2 to 8 mm.

[0036] First, a typical example of a relation of the emission current  $I_e$  and the device current  $I_f$  with the device voltage  $V_f$  is shown in Fig. 4. Note that in Fig. 4, since the emission current  $I_e$  is significantly smaller than the device current  $I_f$ , both are represented by an arbitrary unit.

[0037] As is clear from Fig. 4, the electron emission device of the present

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invention has the following three pathognomonic characteristics for the emission current  $I_e$ .

[0038] First of all, when the device voltage  $V_f$  equal to a certain voltage (referred to as a threshold voltage:  $V_{th}$  in Fig. 5) or more is applied to the electron emission device, the emission current  $I_e$  rapidly increases. On the other hand, when a voltage less than the threshold voltage  $V_{th}$  is applied thereto, the emission current  $I_e$  is not almost detected. Specifically, this electron emission device is a non-linear device having a clear threshold voltage  $V_{th}$  for the emission current  $I_e$ .

[0039] Secondly, since the electron emission device has a characteristic (referred to as a MI characteristic) that the emission current  $I_e$  increases monotonously relative to the device voltage  $V_f$ , the emission current  $I_e$  can be controlled by the device voltage  $V_f$ .

[0040] Thirdly, the emission charges captured at the anode electrode 34 (see Fig. 3) depend on a time for which the device voltage  $V_f$  is applied. Specifically, the charge amount captured by the anode electrode 34 can be controlled by a time for which the device voltage  $V_f$  is applied.

[0041] The emission current  $I_e$  has the MI characteristic relative to the device voltage  $V_f$  and, at the same time, also the device current  $I_f$  sometimes has the MI characteristic relative to the device voltage  $V_f$ . An example of such a characteristic of the electron emission device is the characteristic indicated by the solid lines in Fig. 4. On the other hand, as shown by the dotted line in Fig. 4, the device current  $I_f$  may show a voltage control type negative resistance characteristic (referred to as a VCNR characteristic) relative to the device voltage  $V_f$ . Which characteristic the electron emission device shows depends on a manufacturing method of the electron emission device, measurement conditions and the like. However, in the electron emission device in which the device current  $I_f$  shows the VCNR characteristic relative to the device voltage  $V_f$ , the emission current  $I_e$  has the MI characteristic relative to the device voltage  $V_f$ .

[0042] Next, the arrangement of the electron emission devices in the electron source of the present invention will be described.

[0043] As the arrangement style of the electron emission devices in the electron source of the present invention, enumerated are a ladder type array in which the electron emission device are arrayed in parallel, and a plurality of columns

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are arrayed, each column being composed of the plurality of electron emission devices, both terminals (both device electrodes) of which are respectively coupled by a wiring (referred also to as a common wiring), and an array style in which n-pieces Y-direction wirings are placed on m-pieces X-direction wirings so as to interpose an interlayer insulating layer therebetween, and the X-direction wirings and the Y-direction wirings are respectively coupled to a pair of device electrodes of the electron emission device. This is hereinafter referred to as a simple matrix array style. First, descriptions of this simple matrix array will be made in detail.

[0044] According to the basic characteristic of the foregoing electron emission device, the emission electrons in the electron emission device, each of which is arrayed with the simple matrix array style, can be controlled, in a voltage range exceeding the threshold voltage, by a peak value of a pulse-like voltage and a pulse width thereof, which is applied between the device electrodes facing each other. On the other hand, below the threshold voltage, electrons are not almost emitted. Accordingly, even in the case where the plurality of electron emission devices are arrayed, if the foregoing pulse-like voltage is appropriately applied to the respective device, an electron emission device is selected in accordance with an input signal, and the selected electron emission device can be controlled. Thus, the individual electron emission device is selected to be independently driven only with the simple matrix wiring.

[0045] The simple matrix array is based on such a principle, and an example of the electron source of the present invention. The constitution of the electron source with this simple matrix array will be further described based on Fig. 5.

[0046] In Fig. 5, the substrate 1 is made of the glass plate and the like as described above, and the number and shape of the electron emission devices 54 arrayed on the substrate 1 are suitably set according to the use.

[0047] The m-pieces X-direction wirings 52 have external terminals  $D_{x1}$ ,  $D_{x2}$ , ....., and  $D_{xm}$ , respectively, and are made of a conductive metals or the like formed by use of a vacuum deposition method, a printing method, a sputtering method or the like on the substrate 1. Moreover, a material, thickness and width of the wirings are set so that a voltage is evenly supplied to the plurality of electron emission devices 54.

[0048] The n-pieces Y-direction wirings 53 have external  $D_{y1}$ ,  $D_{y2}$ , ....., and  $D_{yn}$ , respectively, and are formed similarly to the X-direction wirings 52.

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[0049] An interlayer insulating layer (not shown) is formed between the m-pieces X-direction wirings 52 and the n-pieces Y-direction wirings 53, and the wirings are electrically isolated from each other, thus constituting the matrix wiring. Note that both of m and n are a positive integer.

[0050] The interlayer insulating layer (not shown) is  $\text{SiO}_2$  and the like, which are formed by use of a vacuum deposition method, a printing method, a sputtering method or the like, and is formed on the entire surface of the substrate 1 or a part thereof, in which the X-direction wirings 52 are formed, so as to have a desired shape. Particularly, the film thickness, material and manufacturing method of the interlayer insulating layer are suitably set so as to be capable of withstanding a potential difference at crossing portions of the X and Y-direction wirings 52 and 53.

[0051] Moreover, the device electrodes (not shown) of the electron emission device 54, which face each other, are electrically coupled by the m-pieces X-direction wirings 52, the n-pieces Y-direction wiring s 53 and the coupling lines 55 made of a conductive metal, which are formed by use of the vacuum deposition method, the printing method, the sputtering method or the like.

[0052] Herein, the m-pieces X-direction wirings 52, the n-pieces Y-direction wirings 53, the couple lines 55, and the device electrodes facing to each other may be formed by the same material or different materials in the parts of their constituent components or the total thereof, and the materials of them are suitably selected from the foregoing ones of the device electrodes. The wirings coupled to the device electrodes are sometimes generally called a device electrode when the wirings have the same material as that of the device electrode. In addition, the electron emission device 54 may be formed either on the substrate 1 or an interlayer insulating layer (not shown).

[0053] Moreover, to be described in detail, scanning signal application means (not shown) for applying a scanning signal is coupled to the foregoing X-direction wirings 52 in order to scan the column of the electron emission device 54 arrayed in the X-direction in accordance with the input signal.

[0054] On the other hand, to modulate each column of the electron emission devices 54 arrayed in the Y-direction, modulation signal generation means (not shown) for applying a modulating signal is electrically coupled to the Y-direction wirings 53. Moreover, a driving voltage applied to each of the electron emission devices 54 is supplied as a voltage difference between the

scanning signal and the modulating signal, which are applied to the electron emission device 54.

[0055] Next, an example of an image formation apparatus using the electron source of the present invention adopting the foregoing simple matrix array will be described by use of Figs. 6 to 8. Fig. 6 is a basic constitutional view of a display panel 81, Fig. 7 is a drawing showing a fluorescent film 64, and Fig. 8 is a block diagram showing an example of a driving circuit for performing a television displaying in accordance with a TV signal of a NTSC system.

[0056] In Fig. 6, reference numeral 1 denotes a substrate of the electron source in which the electron emission devices are arrayed in the above described manner; 61, a rear plate fixing the substrate 1; 66, a face plate in which a fluorescent film 64, a metal back 65 and the like are formed on the interior surface of a glass substrate 63; and 62, a supporting frame. A casing 68 is constituted by coating flit glass or the like onto the rear plate 61, the supporting frame 62 and the face plate 66 and by baking them in the air or nitrogen gas at 400 °C to 500 °C for ten minutes or more.

[0057] In Fig. 6, reference numerals 52 and 53 are the X and Y-direction wirings coupled to the pair of device electrodes 2 and 2' of the electron emission device 54 respectively, and the X and Y-direction wirings 52 and 53 have the external terminals  $D_{x1}$  to  $D_{xm}$ , and  $D_{y1}$  to  $D_{yn}$ , respectively.

[0058] The casing 68 is constituted by the face plate 66, the supporting frame 62 and the rear plate 61, as described above. However, the rear plate 61 is principally provided with the intention for the reinforcement of the strength of the substrate 1. When the substrate 1 itself possesses sufficient strength, the rear plate 61 as a separate member is unnecessary. The supporting frame 62 may be hermetically attached to the substrate 1, thus constituting the casing 68 by the face plate 66, the supporting frame 62 and the substrate 1. Moreover, a supporting body (not shown) called a spacer is further provided between the face plate 66 and the rear plate 61, whereby the casing 68 having a sufficient strength against the air can be produced.

[0059] Although the fluorescent film 64 is formed of only fluorescent substance 72 in the case of monochrome, the fluorescent film 64 is constituted by a black conductive material 71 and a fluorescent substance 72 called a black stripe (Fig. 7(a)) or a black matrix (Fig. 7(b)) according to the array of the fluorescent substance 72 in the case of the color fluorescent film 64. The object to provide

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the black stripe and the black matrix is to make color mixture and the like inconspicuous by blackening the boundary between the fluorescent substances 72 of three primaries, which are necessary for color displaying. Another object is to suppress the decrease of contrast owing to external reflection in the fluorescent film 74. As the material of the black conductive member 71, not only a material essentially containing graphite ordinarily widely used but also other materials can be used as long as the materials are conductive and show less light transmittance and reflection.

[0060] As the method to coat the fluorescent substance 72 on the glass substrate 73, a deposition method and a printing method are used irrespective of monochrome displaying and color displaying.

[0061] Furthermore, as shown in Fig. 6, the metal back 65 is ordinarily provided on the interior surface side of the fluorescent film 64. The metal back 65 is used for the purpose of enhancing luminance by mirror-reflecting light among light emitted by the fluorescent substance 72 (see Fig. 7) to the glass substrate 63 side, which is to be propagated toward the inside, of acting as an electrode for applying an electron beam acceleration voltage, and protecting the fluorescent substance 72 from damages by collisions of negative ions generated within the casing 68. The metal back 65 can be prepared in such a manner that after the preparation of the fluorescent film 64, the interior surface of the fluorescent film 64 is subjected to a smoothing treatment (usually called filming), and then Al is deposited by use of a vacuum deposition and the like.

[0062] To enhance the conductivity of the fluorescent film 64, in the face plate 66, a transparent electrode (not shown) may be provided on the outer surface side of the fluorescent film 64.

[0063] When the foregoing hermetic attachment is conducted, since the fluorescent substance 72 of each color and the electron emission device 64 must correspond to each other in the case of color displaying, it is necessary to perform full position alignment.

[0064] Inside of the casing 68 is made to be a vacuum of about  $10^{-7}$  Torr through an air exhaustion pipe (not shown), and sealed. Furthermore, immediately before or after the casing 68 is sealed, a gettering treatment is sometimes performed. This is a treatment in which a getter (not shown) arranged at a predetermined position in the casing 68 is heated to form a deposition film. The getter usually contains Ba and the like essentially, and

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serves to maintain a vacuum of, for example,  $1 \times 10^{-5}$  to  $1 \times 10^{-7}$  Torr by the absorption function of the deposition film.

[0065] The foregoing display panel 81 can be driven by, for example, a driving circuit as shown in Fig. 8. Note that in Fig. 8, reference numeral 81 denotes a display panel; 82, a scanning circuit; 83, a control circuit; 84, a shift register; 85, a line memory; 86, a synchronous signal separation circuit; 87, a modulation signal generator; and  $V_x$  and  $V_a$ , DC voltage source.

[0066] As shown in Fig. 8, the display panel 81 is electrically coupled to an external electric circuit through the external terminals  $D_{x1}$  to  $D_{xm}$ , the external terminals  $D_{y1}$  to  $D_{yn}$  and the high voltage terminal Hv. Among these external terminals, a scanning signal is applied to the external terminals  $D_{x1}$  to  $D_{xm}$ , the scanning signals being for sequentially driving an electron emission device group one column by one column (n devices by n devices), in which the electron emission devices provided in the foregoing display panel 81 are matrix-arrayed in the form of matrix of m-columns and n-rows.

[0067] On the other hand, a modulation signal is applied to the external terminals  $D_{y1}$  to  $D_{yn}$ , the modulation signal being for controlling an output electron beam of each electron emission device in one column selected by the foregoing scanning signal. Moreover, a DC voltage of, for example, 10 kV is supplied to the high voltage terminal Hv from the DV voltage source  $V_a$ . This is an acceleration voltage for imparting energy to the electron beam output from the electron emission device, the energy being sufficient for the electron beam to excite the fluorescent substance.

[0068] The scanning circuit 82 comprises m switching elements therein (represented by  $S_1$  to  $S_m$  in Fig. 8 schematically). Each of the switching elements  $S_1$  to  $S_m$  selects one of an output voltage of the DC voltage power source  $V_x$  and 0V (ground level), and electrically coupled to the corresponding one of the external terminals  $D_{x1}$  to  $D_{xm}$  of the display panel 81. Each of the switching elements  $S_1$  to  $S_m$  is operated based on the control signal  $T_{scan}$  output by the control circuit 83, and actually can be constituted easily by combining devices having a switching function like, for example, FETs.

[0069] The foregoing DC voltage source  $V_x$  in this example is set based on the characteristic of the foregoing electron emission device (threshold voltage) so that a driving voltage applied to an electron emission device which is not being scanned is the threshold voltage or less.

[0070] The control circuit 83 has a function to adjust operations of the sections of the circuit so that a proper displaying is carried out based on the image signal input from the outside. Based on a synchronous signal  $T_{sync}$  sent from the synchronous signal separation circuit 86 to be described below, control signals  $T_{scan}$ ,  $T_{st}$  and  $T_{mry}$  are generated for the sections of the circuit.

[0071] The synchronous signal separation circuit 86 is a circuit for separating a synchronous signal component and a luminance signal component from the television signal of the NTSC system input from the outside, and, as well known, can be constituted with the use of a frequency separation (filter) circuit. As is well known, the synchronous signal separated by the synchronous signal separation circuit 86 is composed of a vertical synchronous signal and a horizontal synchronous signal. Herein, for convenience's sake of an explanation, the synchronous signal is illustrated as  $T_{sync}$ . On the other hand, the luminance signal component of the image separated from the foregoing television signal is illustrated as a DATA signal for convenience's sake. This DATA signal is input to a shift register 84.

[0072] The shift register 84 serial/parallel-converts the foregoing DATA signal, which is serial-input thereto time-sequentially, for one line of the image, and operates based on the control signal  $T_{st}$  sent from the foregoing control circuit 83. This control signal  $T_{st}$  may be said alternatively as a shift clock of the shift register 84. Furthermore, the data equivalent to one line of the image (equivalent to driving data of the  $n$  electron emission devices), which has been subjected to the serial/parallel conversion, is output from the foregoing shift register 84 as  $n$ -pieces parallel signals  $I_{d1}$  to  $I_{dn}$ .

[0073] The line memory 85 is a storage device for storing data of one line of the image for a period of time required, and properly stores contents of  $I_{d1}$  to  $I_{dn}$  in accordance with the control signal  $T_{mry}$  sent from the control circuit 83. The stored contents are output as  $I_{d'1}$  to  $I_{d'n}$ , and input to the modulation signal generator 87.

[0074] The modulation signal generator 87 is a signal source for performing a drive modulation for each of the electron emission devices properly in accordance with the corresponding one of the foregoing image data  $I_{d'1}$  to  $I_{d'n}$ , and the output signals from the modulation signal generator 87 are applied to the electron emission devices in the display panel 81 through the terminals  $D_{y1}$  to  $D_{yn}$ .



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[0075] As described above, the election emission device has a clear threshold voltage in the electron emission, and emits electrons on when a voltage exceeding the threshold voltage is applied thereto. Moreover, an emission current changed depending on the change of the application voltage to the electron emission device relative to the voltage exceeding the threshold voltage. Although the degree of the change of the emission current relative to the value of the threshold voltage and the application voltage may change by altering a material, constitution and manufacturing method of the electron emission device, the following can be derived any way.

[0076] Specifically, when the pulse-like voltage is applied to the electron emission device, the electron emission does not occur even when, for example, the voltage equal to the threshold voltage or less is applied. However, when the voltage exceeding the threshold voltage is applied, the election emission occurs. At this time, first, by changing the peak value of the voltage pulse, it is possible to control the intensity of the electron beam output. Secondly, by changing the width of the voltage pulse, it is possible to control the total amount of the charges of the electron beam output.

[0077] Accordingly, as a method of modulating the electron emission device in accordance with the input signal, enumerated are a voltage modulation method and a pulse width modulation method. When the voltage modulation method is performed, the modulation signal generator 87 generates a voltage pulse of a constant length, and a circuit adopting the voltage modulation method capable of modulating the peak value of the pulse properly in accordance with data input thereto is used. Moreover, when the pulse width modulation method is performed, the modulation signal generator 87 generates a voltage pulse of a constant peak value, a circuit adopting the pulse width modulation method capable of modulating the pulse width in accordance with data input thereto is used.

[0078] The shift register 84 and the line memory 85 may adopt a digital signal system or an analog signal system. Any kind of shift register and line memory will do as long as they can perform a serial/parallel conversion of an image signal and storing of the image signal at a predetermined speed.

[0079] When the digital signal system is employed, the output signal DATA of the synchronous signal separation circuit 86 needs to be converted a digital signal. This can be performed by providing an A/D converter in an output

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section of the synchronous signal separation circuit 86.

[0080] Moreover, in association with this, the circuit provided in the modulation signal generator 87 differs a little depending on whether the output signal of the line memory 85 is a digital signal or an analog signal.

[0081] Specifically, in the case of the digital signal and the voltage modulation method, for example, a D/A conversion circuit that has been well known is used as the modulation signal generator 87, and an amplification circuit and the like may be added if necessary. In addition, in the case of the digital signal and the pulse width modulation method, the modulation signal generator 87 can be easily constituted by use of a circuit obtained by combining a high speed oscillator, a counter for counting the number of waves output by the oscillator, and a comparator for comparing an output value of the counter and an output value of the foregoing memory. Moreover, an amplifier may be added thereto if necessary, which amplifies the voltage of the modulation signal, which is output from the comparator and is modulated with respect to its pulse width, to a voltage for driving the electron emission signal.

[0082] On the other hand, in the case of the analog signal and the voltage modulation method, for example, an amplification circuit using an operational amplifier and the like, which have been well known, may be used as the modulation signal generator 87. A level shift circuit and the like may be added if necessary. Moreover, in the case of the analog signal and the pulse width modulation method, a voltage control type oscillation circuit (VCO), for example, which has been well known, may be used. An amplifier for amplifying a voltage of the modulation signal to a voltage for driving the electron emission device, if necessary.

[0083] The image forming apparatus of the present invention, which has the display panel 81 and the driving circuit as described above, can emit electrons from necessary electron emission devices by applying the voltage from the terminals  $D_{x1}$  to  $D_{xm}$  and  $D_{y1}$  to  $D_{yn}$ , and applies a high voltage to the metal back 55 or the transparent electrode (not shown) through the high voltage terminal Hv to accelerate an electron beam. The image forming apparatus can perform television displaying in accordance with a television signal of the NTSC system by excitation/light emission caused by allowing the accelerated electron beam to collide against the fluorescent film 54.

[0084] The above described constitution is a schematic constitution necessary

for obtaining the image forming apparatus of the present invention used for the displaying and the like. Detailed portions such as materials of each member are not limited to the above, and properly selected so as to be suitable for the use of the image forming apparatus. Moreover, the NTSC system is enumerated as the input signal. However, the input signal is not limited to this in the image forming apparatus of the present invention, and other systems such as a PAL system and a SECAM system will do. Moreover, a high quality TV system from a MUSE system down will do, which adopts a TV signal composed of scanning lines of the larger number than the PAL and SECAM systems and the like.

[0085] Next, an example of the electron source adopting the foregoing ladder type array and the image forming apparatus of the present invention using the electron source will be described by use of Fig. 9 and Fig. 10.

[0086] In Fig. 9, reference numeral 1 denotes a substrate; 54, electron emission devices; and 94, common wirings for coupling the electron emission devices 54, the common wirings 94 being provided by ten and having external terminals D<sub>1</sub> to D<sub>10</sub>, respectively.

[0087] The electron emission devices 54 are arrayed in parallel in plural number on the substrate 1. This is called a device column. Then, the device column is arrayed in plural number, thus constituting the electron source.

[0088] By applying a proper driving voltage between the common wirings 94 (for example, the common wiring 94 of the external terminals D<sub>1</sub> and D<sub>2</sub>) of each device column, it is possible to drive each device column independently. Specifically, a voltage exceeding the threshold voltage may be applied to a device column desired to emit an electron beam therefrom, and a voltage lower than the threshold voltage may be applied to a device column desired not to emit the electron beam. With respect to the common wirings D<sub>2</sub> to D<sub>9</sub>, arrayed between the device columns, the application of such a driving voltage can be performed while treating the adjacent common wirings 94, that is, the common wirings 94 for the external terminals D<sub>2</sub> and D<sub>3</sub>, D<sub>4</sub> and D<sub>5</sub>, D<sub>6</sub> and D<sub>7</sub>, and D<sub>8</sub> and D<sub>9</sub> as united one wiring.

[0089] Fig. 10 is a drawing showing a structure of the display panel 91 comprising the electron source of the foregoing ladder type array, which is another example of the electron source of the present invention.

[0090] In Fig. 10, reference numeral 92 denotes a grid electrode; 93, an

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opening for allowing electrons to pass therethrough;  $D_1$  to  $D_m$ , external terminals for applying voltages to respective electron emission devices; and  $G_1$  to  $G_n$ , external terminals coupled to the grid electrode 92. The common wirings 94 between the device columns are formed on the substrate 1 as united one wiring.

[0091] In Fig. 10, the same reference numerals as those in Fig. 6 denote the same members. The display panel of Fig. 10 differs greatly from the display panel 81 using the electron source adopting the simple matrix array shown in Fig. 6 in that the grid electrode 92 is provided between the substrate 1 and the face plate 66.

[0092] The grid electrode 92 is provided between the substrate 1 and the face plate 66 as described above. The grid electrode 92 can modulate an electron beam emitted from the electron emission device 54, and has a structure that the circular opening 93 is by one provided one by one so as to correspond to each electron emission device 54 to allow the electron beam to pass through the stripe-shaped electrode provided perpendicularly to the ladder-arrayed device column.

[0093] The shape and arrangement position of the grid electrodes 92 are not limited to Fig. 10, and the openings 93 may be provided in the form of mesh in plural. The grid electrode 92 may be provided, for example, around the electron emission device 54 or near the electron emission device.

[0094] The external terminals  $D_1$  to  $D_m$ , and  $G_1$  to  $G_n$  are coupled to a driving circuit (not shown). A modulation signal equivalent to one line of the image is applied to the column of the grid electrodes 92 in synchronization with the sequential driving (scanning) of the device column one by one, whereby irradiation of the electron beam onto the fluorescent film 64 can be controlled and the image can be displayed one line by one line.

[0095] As described above, the image forming apparatus of the present invention can be obtained by use of the electron source of the present invention, which adopts any one of the simple matrix array and the ladder type array. The image forming apparatus suitable for display devices of television conference system, computers and the like, in addition to display devices of the foregoing television broadcasting, can be obtained. Moreover, the image forming apparatus of the present invention can be used also as an exposing apparatus incorporated in an optical printer, which is provided with a

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photosensitive drum.

[0096]

[Embodiments]

[Embodiment 1] As a first embodiment of the present invention, the electron emission device shown in Fig. 1 was fabricated.

[0097] First, a Ti of a thickness of 5 nm and Pt of a thickness of 30 nm were deposited in vacuum on a quartz glass substrate by use of a metal mask, thus forming a device electrode. Next, the portion between the device electrode was locally removed by FIB, thus forming a gap having a length L of 240 nm and a width W of 100  $\mu$ m.

[0098] Next, after organic Pd complex solution (prepared by diluting down CCP 4230 made by Okuno Pharmacy Co. Ltd. with butyl acetate to one third) was spin-coated, and subjected to a thermal treatment in the air at 300  $^{\circ}$ C. Further, a thermal treatment was conducted at 180  $^{\circ}$ C in hydrogen air flow of 2 %, which is obtained by diluting the hydrogen air with nitrogen. In this state, fine particles having a diameter  $\phi$  of 3 to 7 nm were formed on the surface of the device in this stage.

[0099] Subsequently, a thermal treatment was conducted for 10 minutes at 500  $^{\circ}$ C in ethylene air flow of 0.1 %, which is obtained by diluting the ethylene air with nitrogen. When this was observed by a scanning electron microscope, it was found that a large number of fibrous carbons extending fibrously with bending portion and having a diameter of 10 to 25 nm were formed in the gap between the electrodes. Pd fine particles and fibrous carbon were not observed on the device electrode, and the Pd fine particles were considered to be absorbed in a Pt electrode.

[0100]  $I_e$  and  $I_f$  of the electron emission device fabricated in the above described manner were measured by the measurement evaluation system shown in Fig. 3.

[0101] As a result, while  $I_e$  gradually increased,  $I_f$  once decreased rapidly, and then increased gradually. Thus,  $I_f$  reached to saturation after about 600 seconds. At this time,  $I_e$  was about 0.5  $\mu$ A, and  $I_f$  was about 0.5 mA.

[0102] [Embodiment 2] The electron emission device was fabricated in the same manner as the embodiment 1 except that the gap between the device electrodes was set to 500 nm, and  $I_e$  and  $I_f$  were measured.  $I_e$  and  $I_f$  were saturated after about 400 seconds, respectively, and the values of  $I_e$  and  $I_f$  were

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almost equal to those of the electron emission device of the embodiment 1.

[0103] In the observation by the scanning electron microscope, similarly to the embodiment 1, it was observed that a large number of fibrous carbons were formed in the gap. Note that the fibrous carbons were few in the center of the gap.

[0104] [Embodiment 3] In a similar manner to that of the embodiment 1, the device electrodes and the gap between the electrodes were formed, and organic Pd complex solution was coated thereon and then, baking at 300 °C was conducted thereon. Thereafter, a thermal treatment was conducted for 10 minutes at 180 °C in 0.1 % ethylene air flow diluted with nitrogen, and subsequently the device electrode and the gap coated with the organic Pd complex solution was heated to 450 °C, thus conducting a thermal treatment for 10 minutes. The electrical characteristic of the electron emission device was almost identical to that of the embodiment 1.

[0105] [Comparison example 1] The device electrodes and the gap between the electrodes were formed according to the steps similar to those of the embodiment 1, and Pd minute particles were formed. Thereafter, the thermal treatment step in ethylene atmosphere was omitted, and  $I_e$  and  $I_f$  were measured. As a result, both of  $I_e$  and  $I_f$  were not observed.

[0106] [Comparative example 2] The electron emission device was fabricated in a similar manner to that of the embodiment 1 except that the gaps between the electrodes are set to 900 nm. When  $I_e$  and  $I_f$  were measured, both of  $I_e$  and  $I_f$  were not observed at all.

[0107] When this electron emission device was observed by a scanning electron microscope, it was found that though the fibrous carbons were formed near the end of the device electrode, the fibrous carbons do not exist in the center of the gap, and the interval between both of the carbons was large. The reason why above described phenomenon occurred is as follows. When the organic Pd solution was coated, the solution concentrated near the end of the electrode due to surface tension of the solution, and the solution is little near the center of the electrode. As a result, the Pd fine particles were not formed at the center of the gap. Accordingly, it was estimated that the fibrous carbon to be deposited at the fine particles as nucleus was hard to be deposited. Therefore, the gap between the fibrous carbons was wide, and  $I_e$  and  $I_f$  were not observed. Specifically, a current did not flow between the device electrodes, and it was

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estimated that the electron emission did not occur.

[0108] [Embodiment 4] The electron source in which the electron emission devices were arrayed with the simple matrix wiring was fabricated. The procedures are shown below.

[0109] After Cr of a thickness of 5 nm and Au of a thickness of 60 nm were sequentially deposited on the cleaned soda lime glass substrate by a vacuum deposition method. Thereafter, photoresist (AZ1370: made by Hext Co. Ltd.,) was coated while rotating a spinner, and baked. Thereafter, a photomask image was exposed and developed, and a resist pattern of a lower wiring was formed. An Au/Cr deposition stacked film was subjected to wet etching, thus forming the lower wiring.

[0110] An interlayer insulating layer formed of a silicon oxide film having a thickness of 0.1  $\mu\text{m}$  was formed by use of a high frequency sputtering method.

[0111] A photoresist pattern for forming contact holes on the deposited silicon oxide film was formed, and the interlayer insulating layer was etched by use of the photoresist pattern as a mask, thus forming the contact holes. The etching was conducted by a RIE (Reactive Ion Etching) method using  $\text{CF}_4$  gas and  $\text{H}_2$  gas.

[0112] A pattern which is to be the device electrode was formed by use of a photoresist (RD-2000N-41: made by Hitachi Chemical Co., Ltd.), and Ti of a thickness of 5 nm and Ni of a thickness of 100 nm were sequentially stacked by use of a vacuum deposition method. The photoresist pattern was dissolved by organic solvent, and the Ni/Ti stacked film was lifted off, thus forming the device electrode.

[0113] After a photoresist pattern for an upper wiring was formed on the device electrode, Ti of a thickness of 5 nm and Au of a thickness of 100 nm were sequentially stacked on the device electrode by use of a vacuum deposition method, and unnecessary portions were removed by lifting-off, thus forming the upper wiring.

[0114] A resist film was formed so as to cover the portion other than the contact hole portion, and Ti of a thickness of 5 nm and Au of a thickness of 500 nm were sequentially deposited by use of a vacuum deposition method. By removing the unnecessary portions by the lifting-off, the contact hole was buried.

[0115] Similarly to the embodiment 1, a gap was formed between the device

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electrodes by FIB. Moreover, similarly to the embodiment 1, organic Pd complex solution was coated by a spinner, and baked in the air at 300 °C, thus converting the dried organic Pd complex solution to PdO. Moreover, a thermal treatment at 180 °C for 10 minutes was conducted in mixed gas flow of N<sub>2</sub> and 2 % H<sub>2</sub>, thus forming Pd fine particles.

[0116] Similarly to the embodiment 1, a thermal treatment at 500 °C for 10 minutes was conducted in 0.01 % C<sub>2</sub>H<sub>2</sub> air flow, thus forming fibrous carbon. When the electron emission device of this electron source was observed by a high resolution SEM (scanning type electron microscope), no fine particles and no fibrous carbon were observed. It was estimated that the Pd fine particles on the device electrode were diffused into the electrode due to the thermal treatment.

[0117] An extraction electrode and a fluorescent plate were attached to the electron source as shown in Fig. 11, and all of the electron emission devices were scan-driven in order of time. The system of Fig. 11 will be described. In the drawing, reference numeral 111 denotes a vacuum bath, and the air is exhausted from the vacuum bath 111 to a vacuum of  $5 \times 10^{-5}$  pa or less by an air exhaustion system (not shown). Reference numeral 112 denotes a window, and reference numeral 114 denotes a device body composed of an electron emission portion (inter-electrode gap), an electrode, a wiring and the like. Reference numerals 115 and 116 denote driving wirings for X and Y-direction lines. Reference numeral 117 denotes a driver for applying pulses suitable for the foregoing wiring. Reference numeral 118 denotes an extraction electrode, which is formed in such a manner that glass, on which an ITO thin film of a transparent electrode is formed, is inserted in a frame made of aluminium, and a fluorescent substance is applied to the under plane thereof.

[0118] Rectangular pulses were applied to the electron emission device by the driver 117 so that the driving voltage was 14 V and the half-selection voltage was 7 V. The extraction electrode voltage was 5 kV.

[0119] When luminescence of the fluorescent substance due to the electron emission was observed by eyes through the window 112, it was confirmed that variations of luminance of among the devices was little in the electron source of this embodiment, and uniformity of the electron emission characteristic was high.

[0120] [Embodiment 5] An image forming member was combined with the



electron source of the embodiment 4 as shown in Fig. 6, and a display device capable of displaying image information provided from various image information sources from, for example, a TV broadcasting down was constructed. A block diagram of the display device is shown in Fig. 12.

[0121] In the drawing, reference numeral 120 denotes a display panel; 121, a driving circuit for driving the display panel 120; 122, a display controller; 123, a multiplexer; 124, a decoder; 125, an I/O interface circuit; 126, a CPU; 127, an image generation circuit; 128, 129 and 130, an image memory interface circuit; 131, an image input interface circuit; 132 and 133, a TV signal receiving circuit; and 134, an input section. (Note that as a matter of course, this display device displays an image and simultaneously reproduces voice when the display receives a signal containing both of video information and speed information like a TV signal, and descriptions for circuits concerning receiving, separation, reproduction, processing and storing of the speech information, which do not relates directly to the features of the present invention and a speaker are omitted)

[0122] Each section will be described along the flow of the image signal below.

[0123] First, the TV signal receiving circuit 133 is a circuit for receiving the TV image signal transmitted by use of a radio transmission system such as radio wave and spatial optical communication. A system of the TV signal received is not particularly limited, and various systems such as a NTSC system, a PAL system and a SECAM system will do. Moreover, a TV signal composed of a large number of scanning lines (so called a high quality TV from, for example, a MUSE system down) is a signal source suitable for utilizing the advantages of the foregoing display panel, which fits a large area and a large number of pixels. The TV signal received by the TV signal receiving circuit 133 is output to the decoder 124.

[0124] Furthermore, the image TV signal receiving circuit 132 is a circuit for receiving a TV image signal transmitted by use of a cable transmission system such as a coaxial cable and an optical fiber. A system of the TV signal received is not particularly limited like the foregoing TV signal receiving circuit 133, and also the TV signal received by this circuit is output to the decoder 124.

[0125] Furthermore, the image input interface circuit 131 is a circuit for taking in an image signal supplied from the image input apparatus such as a TV camera and an image reading scanner, and the image signal taken in is output

to the decoder 124.

[0126] Moreover, the image memory interface circuit 130 is a circuit for taking in an image signal stored in a video tape recorder (hereinafter referred to as a VTR), and the image signal taken in is output to the decoder 124.

[0127] Furthermore, the image memory interface circuit 129 is a circuit for taking in the image signal stored in a video disc, and the image signal taken in is output to the decoder 124.

[0128] Furthermore, the image memory interface circuit 128 is a circuit for taking in an image signal from an apparatus like a still image disc, which stores still image data, and the still image data taken in is output to the decoder 124.

[0129] The I/O interface circuit 125 is a circuit for coupling this display device, an external computer, a computer network, and an output apparatus such as a printer. As a matter of course, the I/O interface circuit 125 inputs/outputs the image data and characters/graphic information. In some cases, the I/O interface circuit 125 can inputs/outputs a control signal and numerical data between the outside of this display device and the CPU 126 provided in this display device.

[0130] Furthermore, the image generation circuit 127 is a circuit for generating display image data based on image data and character/graphic information input thereto from the outside through the foregoing I/O interface circuit 125 and based on image data and character/graphic information output from the CPU 156. In the inside of this circuit, circuits necessary for generating the image from a rewritable memory for storing, for example, image data and character/graphic information, a read only memory storing an image pattern corresponding to a character code, and a processor for an image processing down are incorporated.

[0131] The display image data generated by this circuit is output to the decoder 124, and can be output to an external computer network and a printer through the foregoing I/O interface circuit 125 in some cases.

[0132] Furthermore, the CPU 126 performs an operation control of this display device and operations concerning a generation, selection and edition of the display image.

[0133] For example, the CPU 126 outputs a control signal to the multiplexer 123, properly selects the image signals to be displayed on the display panel, and combines them. Furthermore, at this time, the CPU 126 generates the control

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signal to a display panel controller in accordance with the image signal to be displayed, and properly controls an operation of the display device including an image display frequency, a scanning method (for example, an interlace or a non-interlace), and the number of scanning lines of one screen.

[0134] Furthermore, the CPU 126 directly outputs the image data and the character/graphic information to the foregoing image generation circuit 127, or inputs the image data and the character/graphic information by accessing the external computer and the memory through the foregoing I/O interface circuit 125.

[0135] Note that as a matter of course, the CPU 126 may have to do with operations other than these operations. For example, the CPU 126 may have directly to do with functions to generate and process information like, for example, personal computer and word processors.

[0136] Alternatively, as described above, the CPU 126 is connected to an external computer network through the I/O interface circuit 125, and may perform an operation such as a numerical computation in cooperation with external equipment.

[0137] Moreover, the input section 134 is a circuit for inputting an instruction, a program, or data to the foregoing CPU 126 through the user, and various input devices including, for example, a joy stick, a bar code reader and a voice recognition apparatus in addition to a key board and a mouse can be used as the input section 134.

[0138] Furthermore, the decoder 124 is a circuit for inversely converting various image signals, which are input from the foregoing image generation circuit 127 and the foregoing TV signal receiving circuit 133 to a three primary color signal, a luminance signal, an I signal or a Q signal. Note that as shown by the dotted lines, the decoder 124 should comprise an image memory therein. The reason why the decoder 124 comprises the image memory is to deal with a TV signal requiring the image memory in the inverse conversion. Moreover, this is because, by providing the image memory, advantages that displaying of the still image becomes easier, and advantages that image processing and edition from thinning, an interpolation, an enlargement, a reduction, and synthesis of the image can be performed easily in combination with the foregoing image generation circuit 127 and CPU 126, are created.

[0139] Furthermore, the multiplexer 123 properly selects a display image based

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on the control signal input from the foregoing CPU 126. Specifically, the multiplexer 123 selects a desired image signal among the image signals that have been subjected to the inverse conversion, which are input from the decoder 124, and outputs the selected image signal to the driving circuit 121. In this case, the image signal is switched within an image displaying time to select the image signal, whereby the different images can also be displayed in different areas by dividing one screen into the plurality of areas as so called multi-screen TV.

[0140] Furthermore, the display panel controller 122 is a circuit for controlling an operation of the driving circuit 121 based on the control signal input from the foregoing CPU 126 thereto.

[0141] First, with respect to a basic operation of the display panel, a signal for controlling an operation sequence of, for example, a driving power source (not shown) of the display panel is output to the driving circuit 121.

[0142] Furthermore, with respect to the driving method of the display panel, for example, a signal for controlling, for example, an image display frequency and a scanning method (for example, an interlace or a non-interlace) is output to the driving circuit 121.

[0143] Furthermore, a control signal relating to an adjustment of the image including luminance, contrast, tone and sharpness of the display image is sometimes output to the driving circuit 121 depending on circumstances.

[0144] Furthermore, the driving circuit 121 is a circuit for generating a driving signal which is applied to the display panel 120, and the driving circuit 121 operates based on the image signal input from the foregoing multiplexer 123 and the control signal input from the foregoing display panel controller 122.

[0145] The function of each section is described in the above. It is possible to display the image information input from various image information sources on the display panel 120 in this display device with the constitution shown in Fig. 12. Specifically, after various image signals from the TV broadcasting down is subjected to the reverse conversion in the decoder 124, the image signals are properly selected in the multiplexer 123, and input to the driving circuit 123. On the other hand, the display controller 122 generates the control signal for controlling the operation of the driving circuit 121 in accordance with the image signal to be displayed. The driving circuit 121 applies the driving signal to the display panel 120 based on the foregoing image signal and the control signal.

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Thus, the image is displayed in the display panel 120. A series of operations are collectively controlled by the CPU 126.

[0146] Furthermore, in this display device, the image memory built in the foregoing decoder 124, the image generation circuit 127 and the CPU 126 participate in the operations of the display device. Therefore, not only the image information selected among the plurality of image information is displayed, but also the image processing for the image information to be displayed including, for example, an enlargement, reduction, rotation, movement, edge emphasis, thinning, interpolation, color conversion, and conversion of an aspect ratio of the image, and image edition including a synthesis, an erasion, a connection, a switch, and fitting can be performed. Although the descriptions of this embodiment did not mention the following, a dedicated circuit for processing and editing voice information may be provided similarly to the foregoing image processing and image edition.

[0147] Accordingly, one unit of this display device can have functions such as a display device of a TV broadcasting, a terminal device of a TV conference, an image edition device dealing with a still picture and a moving picture, a terminal device of a computer, an OA terminal device from a word processor down, and a game machine, and has a very wide application range as industrial and consumer display devices.

[0148] Note that, Fig. 12 shows nothing but an example of the display device using the display panel having the electron emission device as the electron source, and, as a matter of course, limitations are not made to this. For example, circuits concerning unnecessary functions from the viewpoint of intended end-usage may be omitted among the constituent components of Fig. 12. Moreover, on the contrary, constituent components may be added depending on the intended end-usage. For example, when the this display device is applied to a TV telephone, a receiving/transmission circuit and the like including a TV camera, a voice microphone, an illuminator, a modem and the like should preferably added thereto.

[0149] In this display device, since the display panel using the electron emission device as the electron source above all can be easily made to be thin, the depth of the display device can be made to be small. In addition, the display panel using the electron emission device as the electron source can be easily manufactured so as to have a large screen and exhibits high luminance.

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Furthermore, the display panel is excellent in a characteristic of an angle of field. Accordingly, the display device can display an impressive image exhibiting sense of reality with good visibility.

[0150] Moreover, since the electron source of the present invention shows uniform electron emission characteristic among the electron emission devices, the display device can form a high quality a formed image, exhibits a high quality, and can display an image with a high definition.

[0151]

[Effects of the Invention] As described above, according to the present invention, an electron emission device showing a good electron emission characteristic can provide with high reliability, and particularly complicated steps and effective materials are not used in fabricating the electron emission device. Accordingly, in the electron source of the present invention using the plurality of electron emission device and in the image forming apparatus, since luminance of luminous points formed by the devices are even and uniform, formation of a high quality image is possible.

[Brief Description of the Drawings]

[Figure 1] Fig. 1 is a basic constitutional view of an electron emission device of the present invention.

[Figure 2] Fig. 2 is a drawing showing an example of manufacturing steps of the electron emission device of the present invention.

[Figure 3] Fig. 3 is a drawing showing a measurement evaluation system for evaluating an electron emission characteristic of the electron emission device of the present invention.

[Figure 4] Fig. 4 is a drawing showing the electron emission characteristic of the electron emission device of the present invention.

[Figure 5] Fig. 5 is a schematic view of a simple matrix electron source of the present invention.

[Figure 6] Fig. 6 is a drawing showing an embodiment of an image forming apparatus of the present invention.

[Figure 7] Fig. 7 is a drawing showing a fluorescent film used in the image forming apparatus of the present invention.

[Figure 8] Fig. 8 is a block diagram of the embodiment of the image forming apparatus of the present invention.

[Figure 9] Fig. 9 is a schematic view of a ladder type electron source of the

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present invention.

[Figure 10] Fig. 10 is a drawing showing an image forming apparatus of the present invention using the ladder type electron source.

[Figure 11] Fig. 11 is a drawing showing a measurement evaluation system of the electron source of the present invention.

[Figure 12] Fig. 12 is a block diagram of an application example of an image forming apparatus of an embodiment 4 of the present invention.

[Explanations of Reference Numerals]

- 1        insulating substrate
- 2, 2'    device electrode
- 3        deposit essentially containing carbon
- 21       metal minute particles
- 30       current meter
- 31       power source
- 32       current meter
- 33       high voltage power source
- 34       anode electrode
- 35       vacuum apparatus
- 36       air exhaustion pump
- 52       X-direction wiring
- 53       Y-direction wiring
- 54       electron emission device
- 55       coupling line
- 61       rear plate
- 62       supporting frame
- 63       glass substrate
- 64       fluorescent film
- 65       metal back
- 66       face plate
- 68       casing
- 71       black conductive material
- 72       fluorescent body
- 81       display panel
- 82       scanning circuit
- 83       control circuit

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- 84 shift register
- 85 line memory
- 86 synchronous signal separation circuit
- 87 modulation signal generator
- 92 grid electrode
- 93 opening
- 94 common wiring
- 111 vacuum bath
- 112 window
- 114 device body
- 115 X-direction driving wiring
- 116 Y-direction driving wiring
- 117 driver
- 118 extraction electrode
- 119 power source
- 120 display panel
- 121 driving circuit
- 122 display panel controller
- 123 multiplexer
- 124 decoder
- 125 I/O interface
- 126 CPU
- 127 image generation circuit
- 128 image memory interface
- 129 image memory interface
- 130 image input memory interface
- 131 image memory interface
- 132 TV signal receiving circuit
- 133 TV signal receiving circuit
- 135 input section
- 130 display panel



Fig. 1

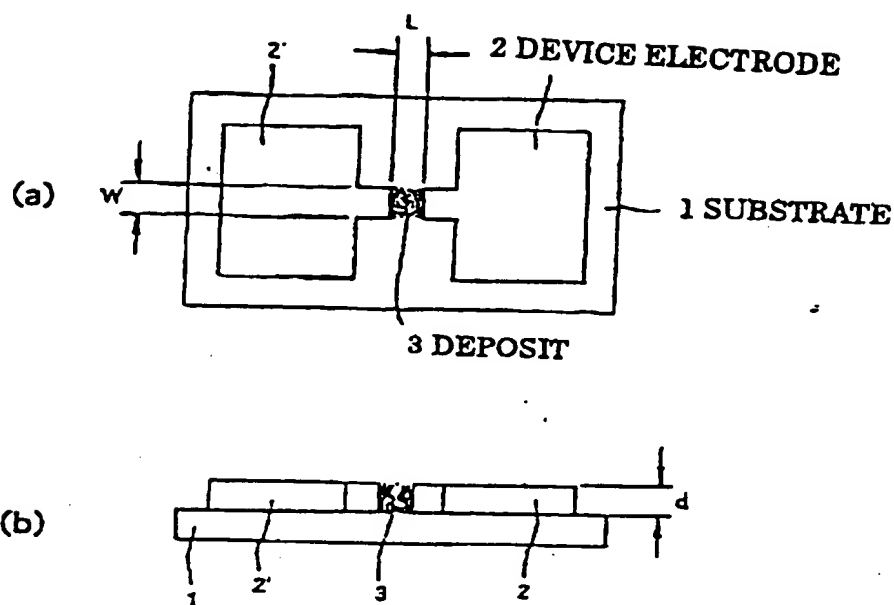
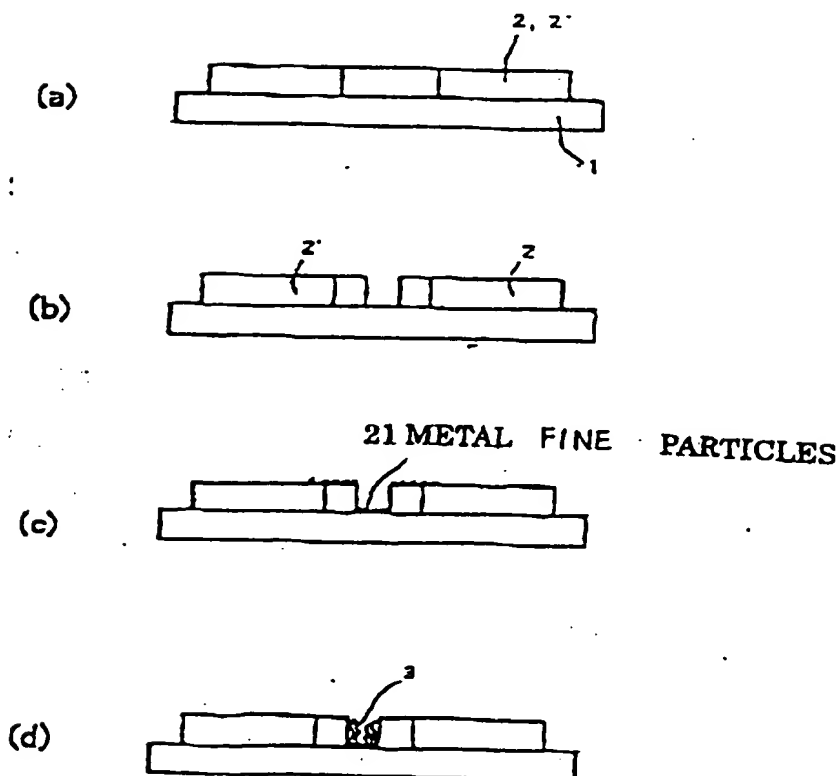


Fig. 2



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Fig.3

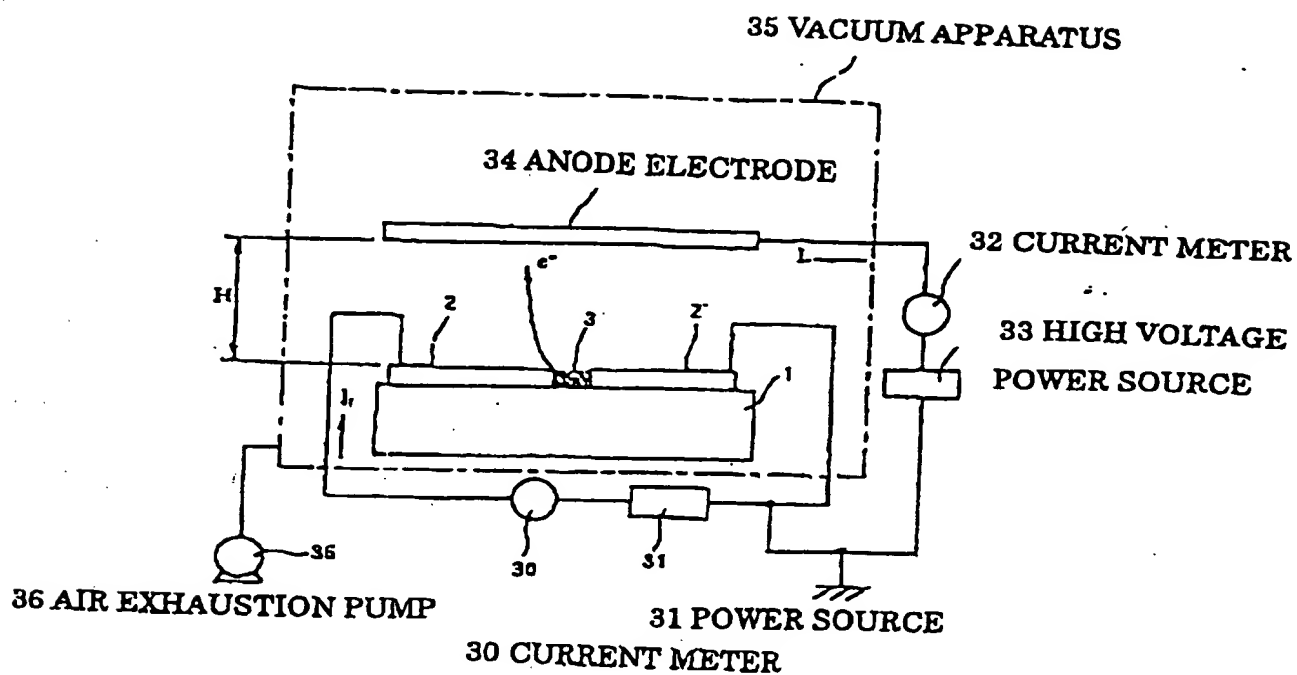
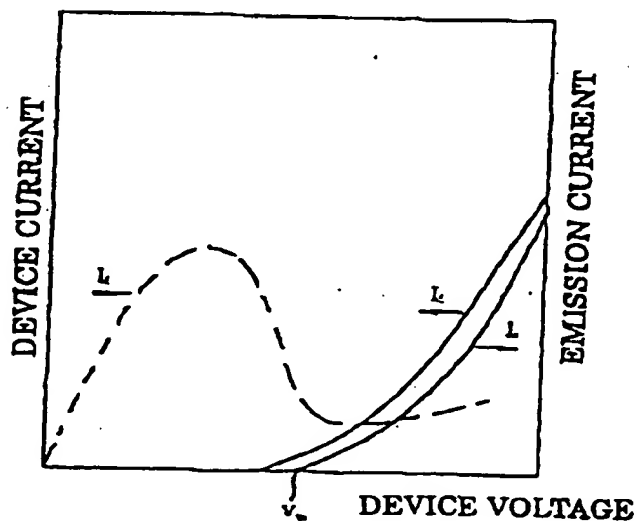


Fig. 4



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Fig. 5

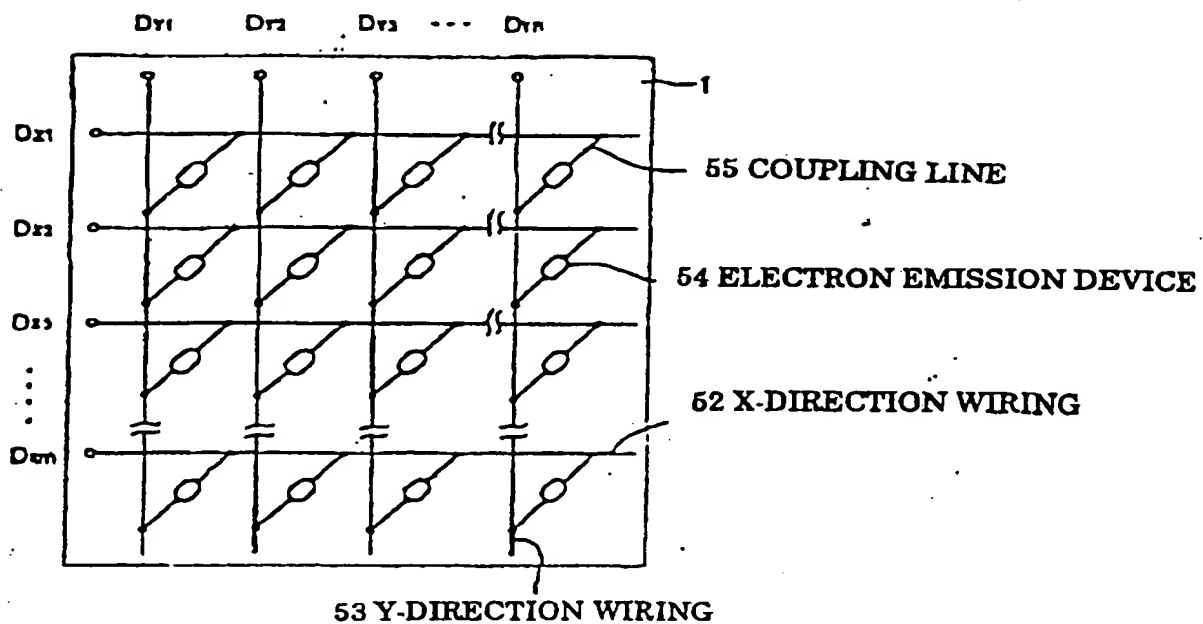
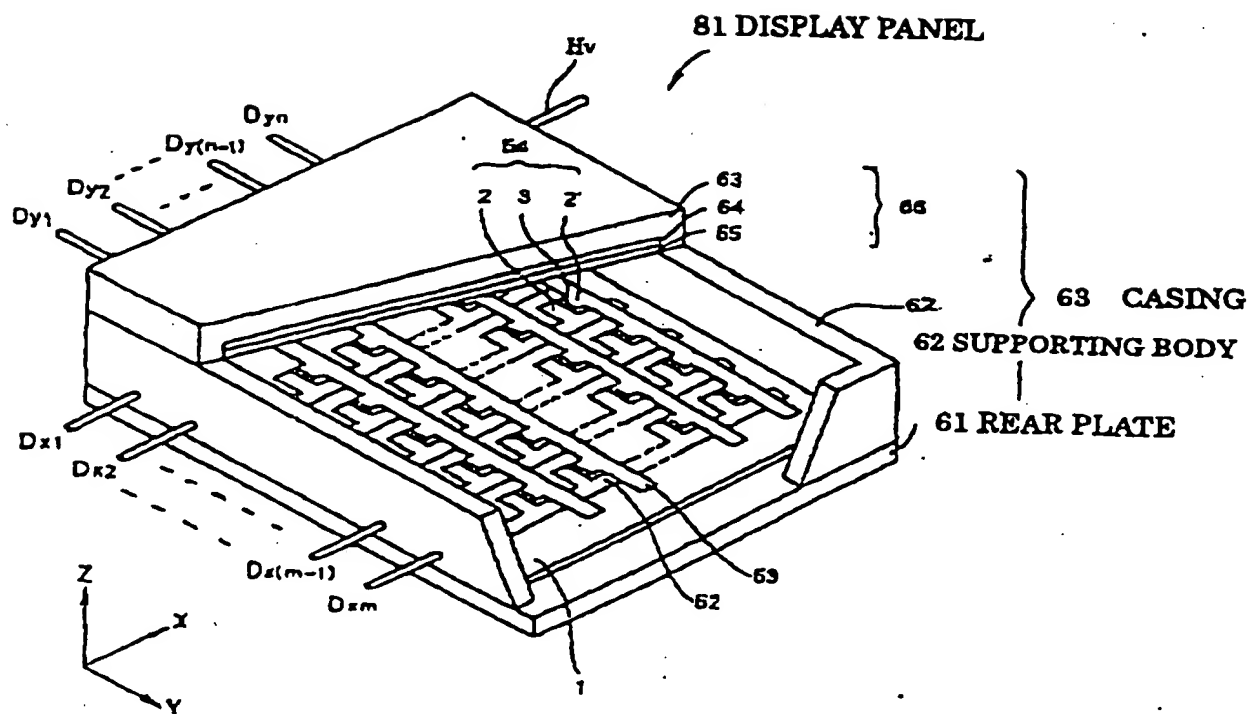


Fig. 6



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Fig. 7

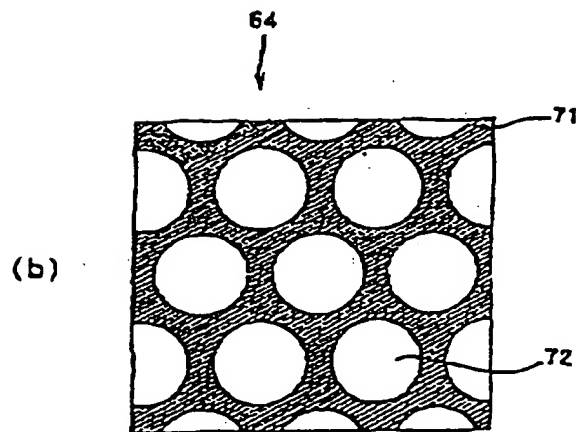
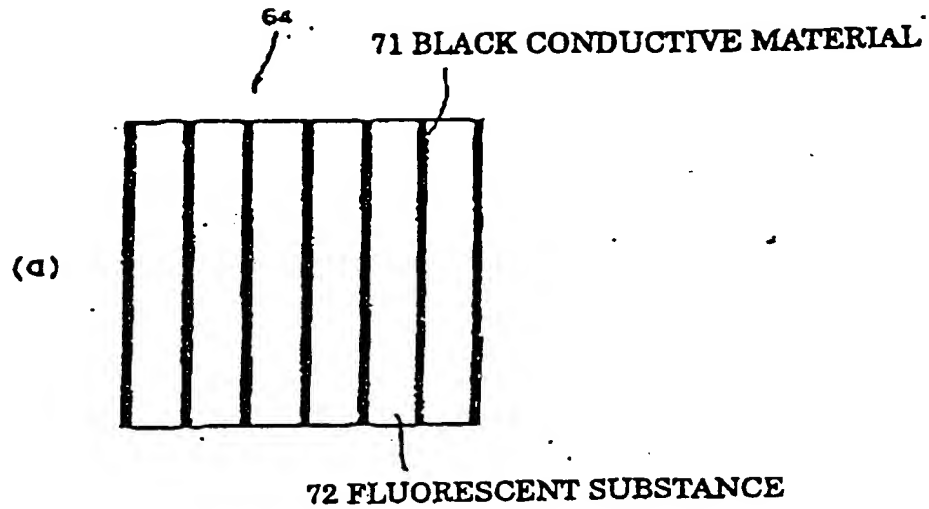


Fig. 8

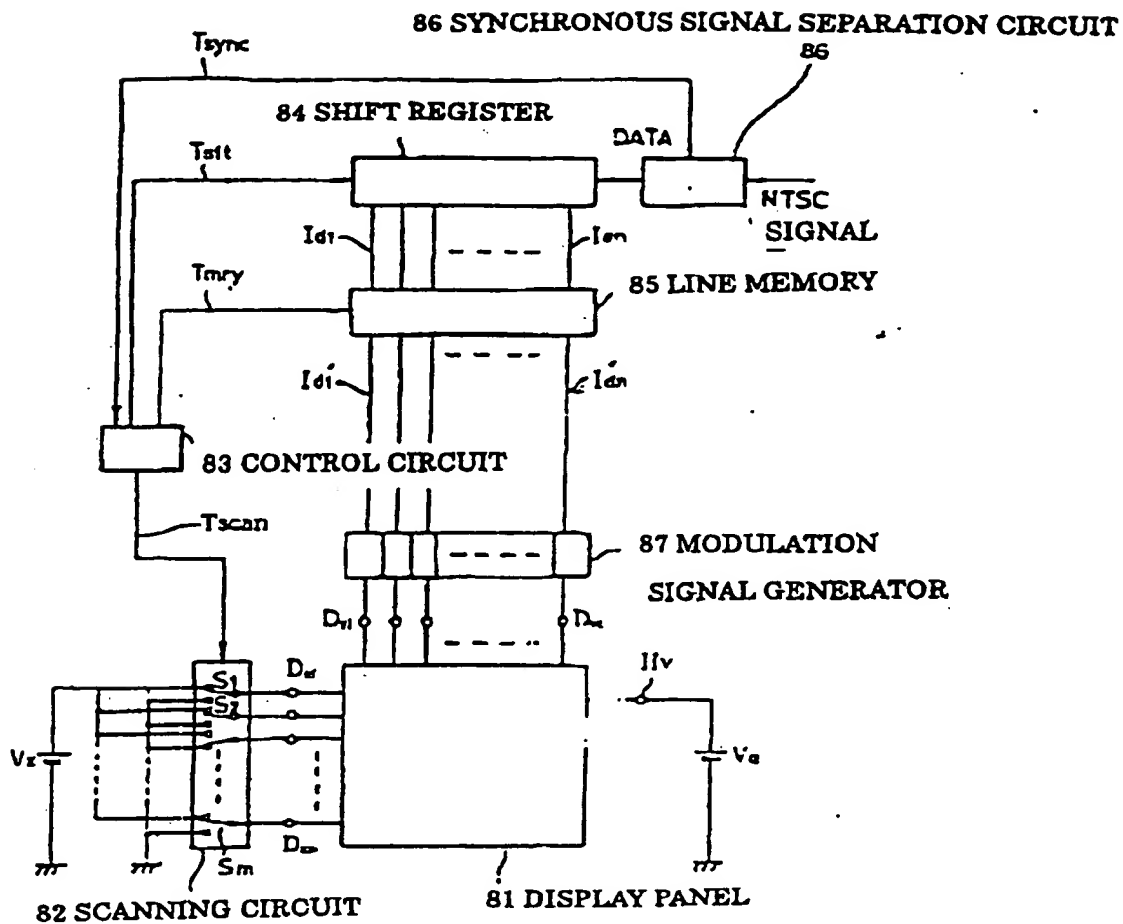
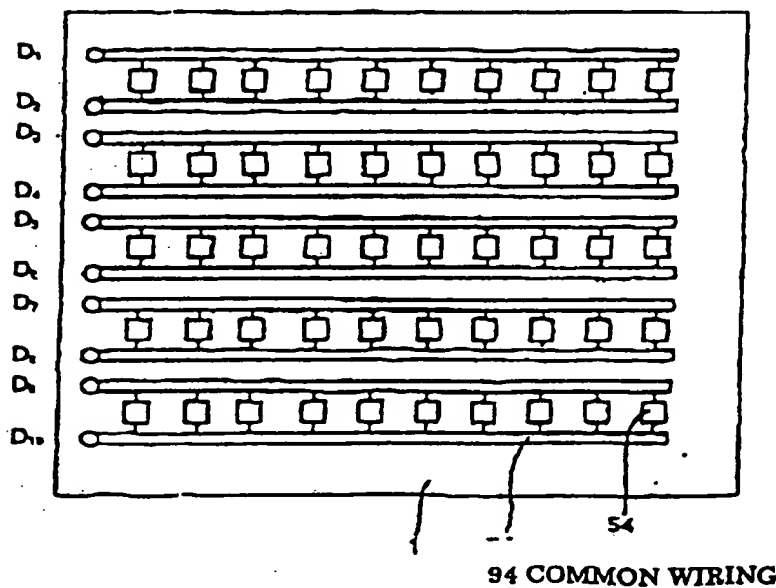
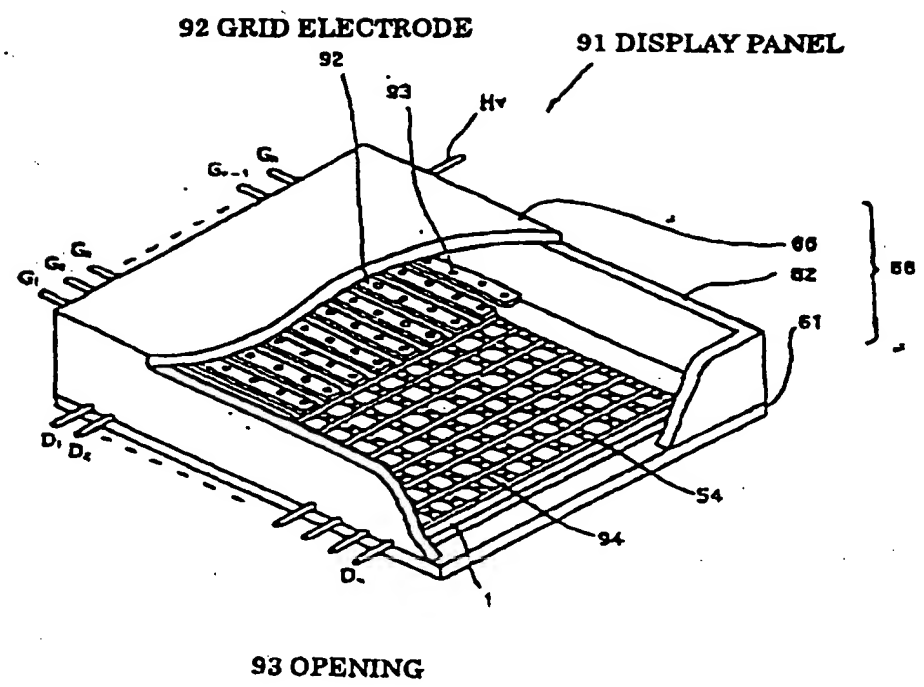


Fig. 9



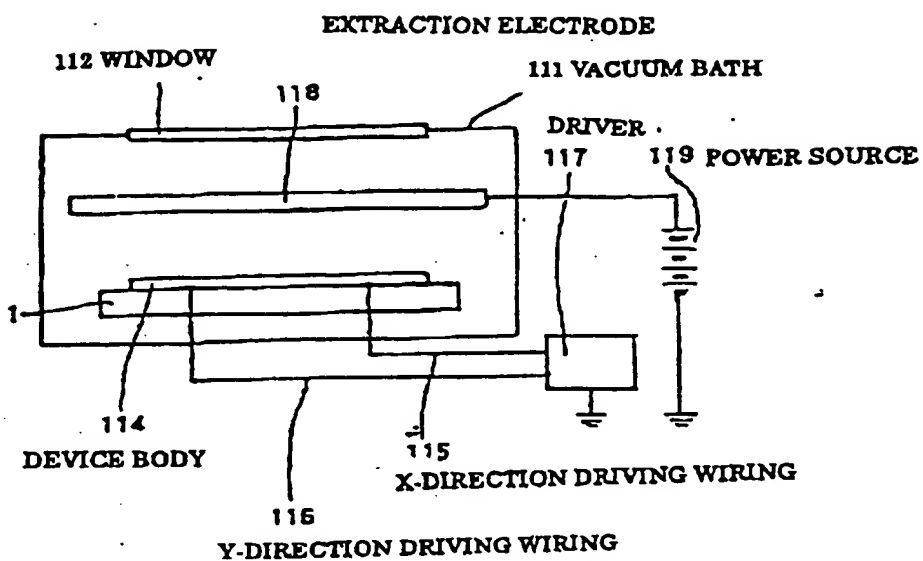
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Fig.10



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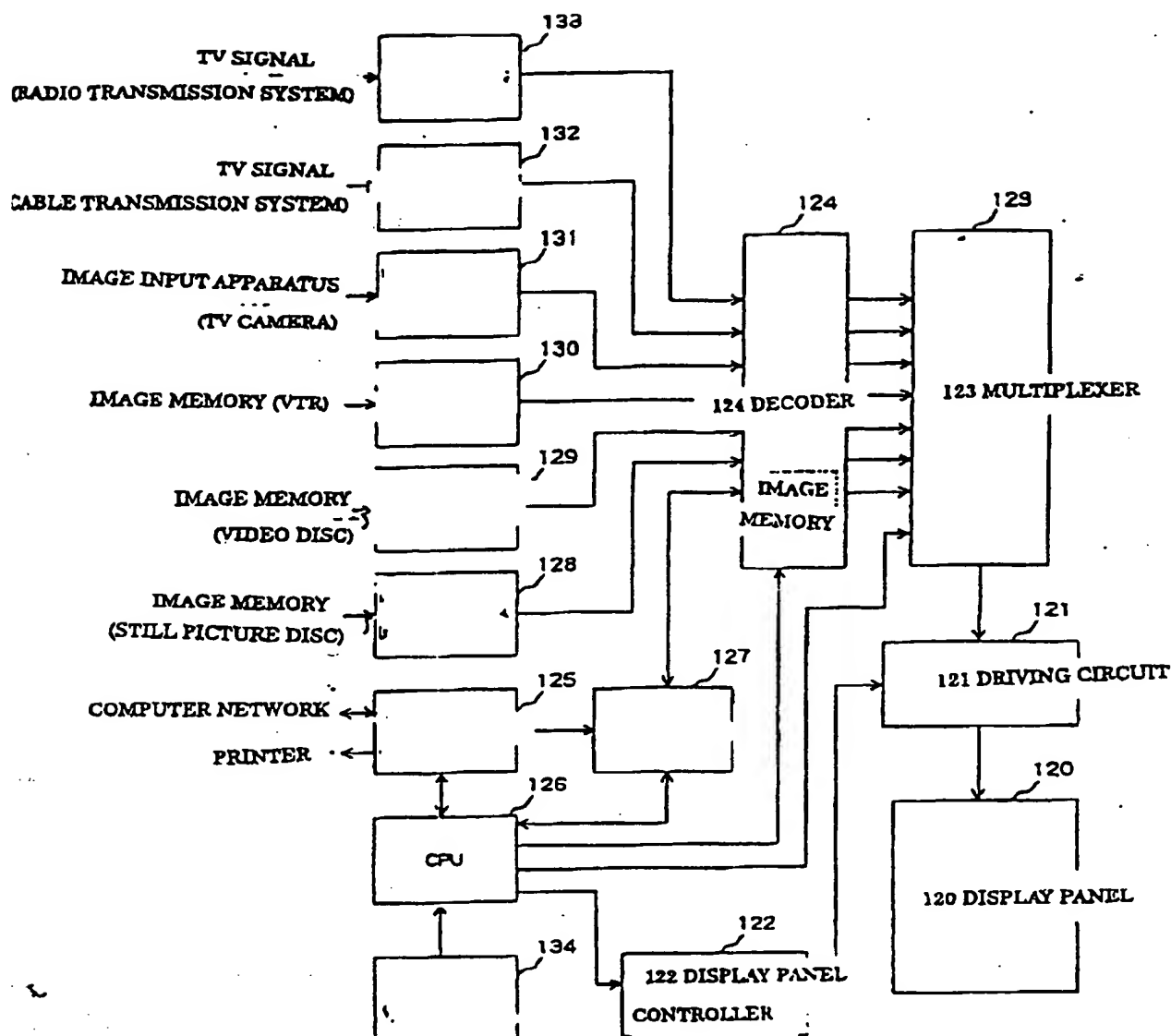
Fig. 11





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Fig. 12



125 I/O INTERFACE CIRCUIT

127 IMAGE GENERATING CIRCUIT

128 IMAGE MEMORY INTERFACE CIRCUIT

129 IMAGE MEMORY INTERFACE CIRCUIT

130 IMAGE MEMORY INTERFACE CIRCUIT

131 IMAGE MEMORY INTERFACE CIRCUIT

132 TV SIGNAL RECEIVING CIRCUIT

133 TV SIGNAL RECEIVING CIRCUIT

134 INPUT SECTION (KEY BOARD, MOUSE AND THE LIKE)